Wind Climatology Literature Review

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The National Centers for Environmental Prediction (NCEP) reanalysis dataset was commissioned to provide a long-term record of global analyses of atmospheric fields in support of the needs of research and climate monitoring communities (Kalnay et al., 1996). Since the product has been in existence it has been used to initiate weather and climate forecast models and to monitor atmospheric phenomenon such as atmospheric winds, temperature, pressure, precipitation, surface fluxes, and many others (Kistler et al., 2001). In 2008, the BAMS State of the Climate publication was the first in the series of annual reports to include data from the NCEP reanalysis dataset, including atmospheric winds, and set a precedent for using the dataset in a climate monitoring setting (Peterson et al., 2009).

The NCEP reanalysis dataset uses weather observations taken from land surface measurements, ships, rawinsondes, pibals, aircraft, satellites, and other platforms. Data assimilation techniques and numerical models are used to extrapolate the data to regions without direct observations in an attempt to yield an estimate with less uncertainty than either the model prediction or observations alone (Fitzmaurice and Bras, 2008; Kalnay et al., 1996). The numerous variables included in the reanalysis are divided into three categories depending upon their basis on direct observations or model output. The class 'A' variables rely mostly on observations and include wind and pressure measurements. According to Kistler et al. 2001, this makes the analyzed tropospheric wind field the most accurate variable included in the entire reanalysis dataset because it is less impacted by model parameterizations. Also, the consistency in the wind measurement technique over time makes the fields less susceptible to changes in observation systems (Trenberth et al. 2001; Kistler et al. 2001).

Several validation studies have been conducted on the accuracy of the wind reanalysis. The studies highlight both the weaknesses and strengths of the dataset. The majority of these studies were conducted in oceanic or polar regions, where atmospheric observations are sparse (Bromwich and Wang, 2005; Putman et al. 2000; Schafer et al. 2003; Smith et al. 2001; Swail and Cox 2000; Wu and Xie, 2003) . In these locations, there is more of a reliance on the model for spatial completeness resulting in a higher probability of error due to the model parameterizations (Bromwich and Wang, 2005; Goswami and Sengupta, 2003; Schafer et al. 2003; Wu and Xie, 2003). If an observation in a data sparse region is significantly different than the model data, it will be rejected from the reanalysis (Kalnay et al. 1996; Schafer et al. 2003). Swail and Cox, 2000 found issues within the wind dataset when there were extratropical storms present. Peak winds were systematically underestimated in major jet-streak features propagating about intense extratropical cyclones. Winds within tropical cyclones were also poorly resolved due to the coarse grid scale. In situ marine observations assimilated into the reanalysis have inherent issues including the height of ship observations not being taken into account as well as averaging intervals not being reported with the observation (Cardone et al., 1990). These marine issues would not directly impact the wind reanalysis over the U.S., and the winds within large cyclones, both tropical and extratropical, would likely be averaged out over the longer timescales (months and seasons) this product examines.

Kumar and Anandan, 2009 found that areas with significant terrain also pose a problem in the reanalysis of wind. Terrain affects the low level flow through the development of gravity waves, blocking, and thermal forcing. Data taken at several locations in the U.S. Mountain West are typically under the influence of these topographic effects. The reanalysis relies heavily on direct observations of the wind, so the reanalysis in the boundary layer tends to be more accurate than wind measurements aloft across complex terrain (Kumar and Anandan, 2009). The handling of the winds further from observations can be problematic, due to the data assimilation and model not being able to accurately represent complex terrain flows. It is important to take these factors into account when examining the wind reanalysis in mountains regions.

Wind fields from the NCEP reanalysis are at least as skillful as the best analyses produced by other operational Numerical Weather Prediction centers including the ECMWF, who already produce wind climatologies from their reanalysis data (Swail and Cox, 2000). Although the NCEP wind reanalysis has well documented issues, we are confident that the low-level reanalysis wind data over the contiguous U.S. is more than adequate to study long term regional trends. Studies have shown that the dataset performs best over regions with a dense observational network (Betts et al. 1996), and that is the case for the United States. Surface wind observations are widespread, while upper-air observations are taken from a systematic balloon network across the country. It is shown that the wind reanalysis performs best at lower levels in the atmosphere (Bromwich and Wang, 2005; Smith et al. 2001) , and by using the .995 sigma height level we are minimizing the affects of the surface and avoiding the problematic upper levels of the atmosphere . Schafer et al., 2003 found that by looking at longer averaging periods the variances of the reanalysis winds approach the variances in actual wind observations. This is promising given the scope of this wind climatology. However, t his suggests that the reanalysis is most likely missing local processes such as sea breezes and other diurnal scale phenomenon (Schafer et al., 2003). The aim of this climatology is not study these wind features on small time or spatial scales, but to study longer term regional trends.

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